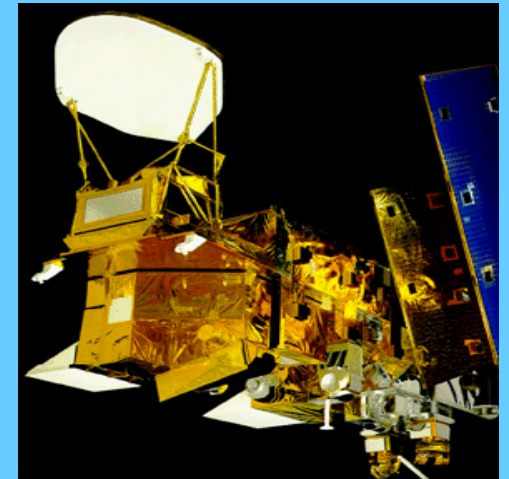


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Atmospheric Infrared Sounder on EOS Aqua Satellite

with Emphasis on Level 2 Products
International Radiation Symposium

August 2004
Busan, Korea

**S-Y Lee, E Fetzer, S Granger, B Lambrigtsen,
E Manning, E Olsen, and T Pagano**

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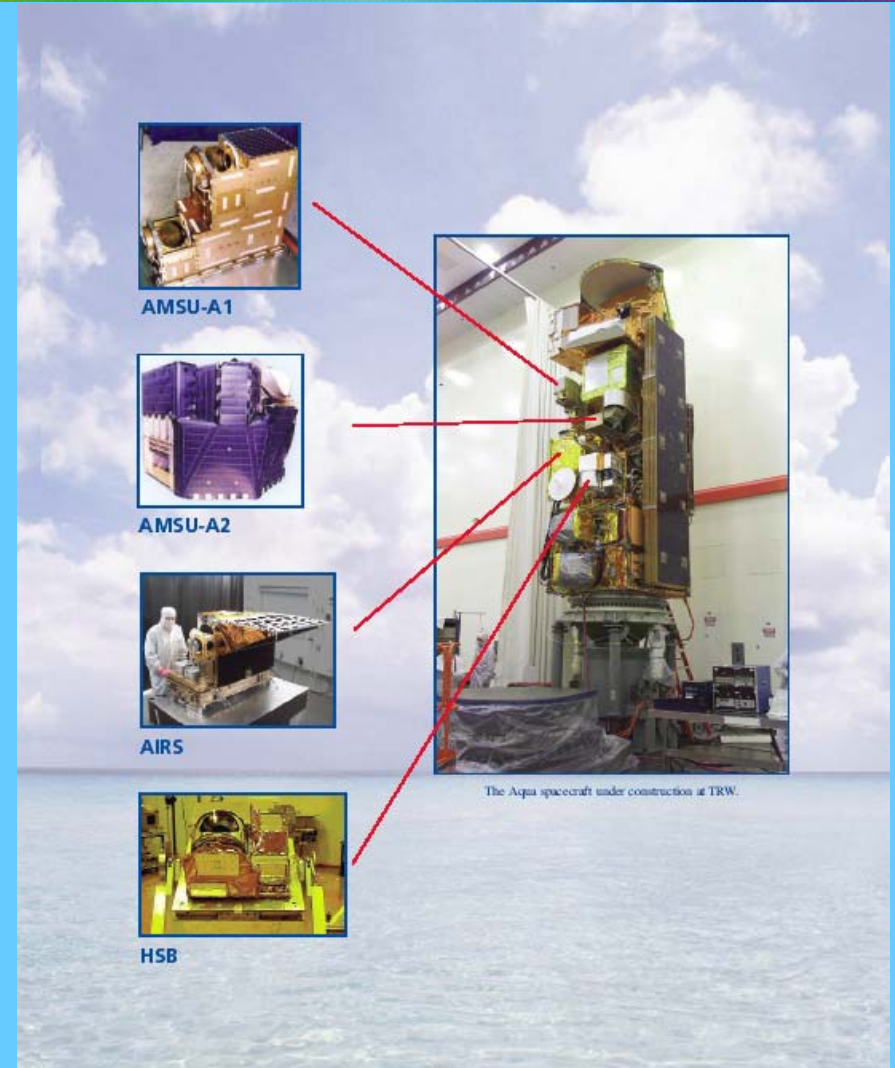


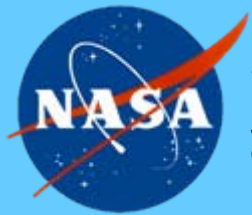
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AIRS on EOS Aqua

- **Remote Sensing of the Earth's Atmosphere with radiosonde accuracy**
- **AIRS operates with two MW sounders, AMSU and HSB**
- **Dual Applications**
 - **Climate Research**
 - **Numerical Weather Prediction**

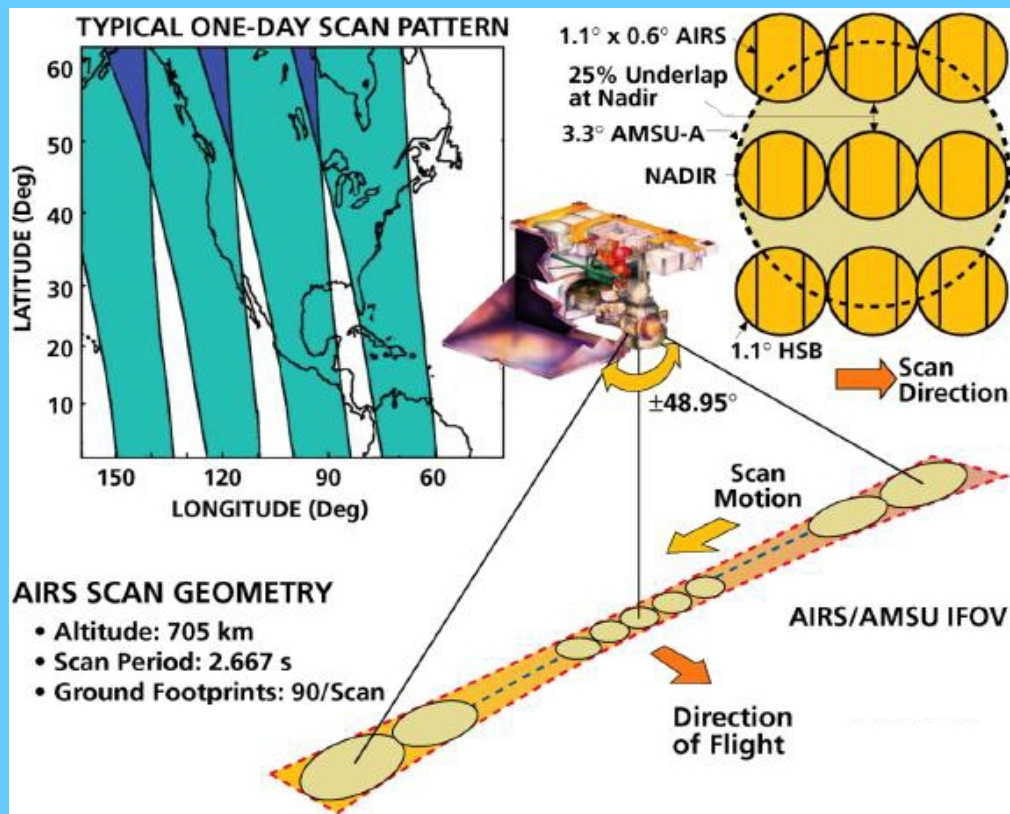




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The AIRS Viewing Geometry



- Aqua is on 1:30 PM ascending sun-synchronous orbit at altitude 705 km
- AMSU footprint, 45 km across at nadir, contains 9 AIRS spectra
 - *This is the retrieval granularity.*
 - *324,000 retrieval attempts per day*
 - *Successful AMSU/HSB sounding 90+ percent*
 - *Successful combined MW/IR sounding 40 - 60 percent*
- Viewing swath 30 AMSU footprints or ~1650 km wide.
 - *Covers most of globe everyday*
 - *Covers much of globe twice a day*
 - *1:30 AM/PM*



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Spectral Coverage of Aqua Sounding Instrument Suite

| | |
|-----------------------|---|
| AIRS Vis/Nr IR | 4 channels 0.40 - 0.95 μm Footprint 2 km |
| AIRS InfraRed | 2378 channels 3.7 - 15.4 μm (650 - 2700 cm^{-1}), $\nu/\delta\nu \sim 1200$ Footprint 15 km, IFOV 1.1 degree |
| AMSU | 15 channels 23 - 90 GHz Footprint 45 km, IFOV 3.3 degree |
| HSB* | 4 channels 150 - 183 GHz Footprint 15 km, IFOV 1.1 degree |

*** Stopped operating in Feb 2003**



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AIRS/AMSU/HSB Data Products

Radiance Products (Level 1B)

AIRS IR Radiance

AIRS VIS/NIR Radiance

AMSU Radiance

HSB Radiance

RMS Uncertainty*

3%

20%

0.25-1.2 K

1.0-1.2 K

Horizontal Resolution

15 x 15 km

2.3 x 2.3 km

45 x 45 km

15 x 15 km

Standard Core Products (Level 2)

Cloud Cleared IR Radiance

Sea Surface Temperature

Land Surface Temperature

Temperature Profile

Humidity Profile

Total Precipitable Water

Fractional Cloud Cover

Cloud Top Height

Cloud Top Temperature

1.0K

0.5K

1.0K

1K

15%

5%

5%

0.5 km

1.0 K

45 x 45 km

45 x 45 km

45 x 45 km

45 x 45 km

45 x 45 km

45 x 45 km

15 x 15 km

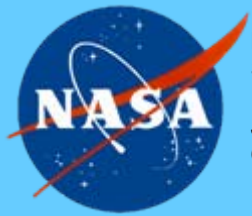
45 x 45 km

45 x 45 km

Vertical
Resolution

1 km below 700 mb
2 km 700-30 mb

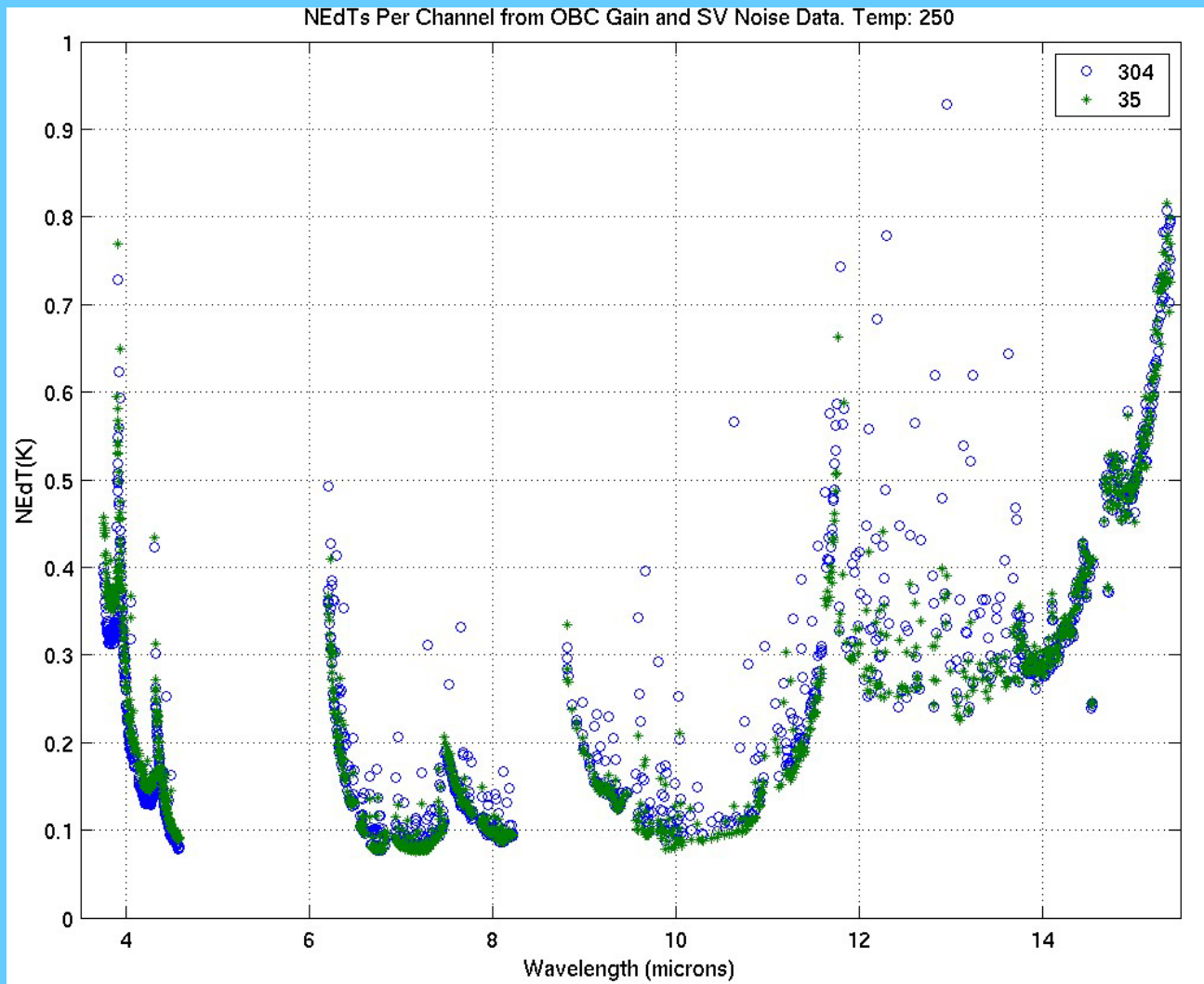
2 km in troposphere



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AIRS NeDT at 250K



S. Gaiser, JPL

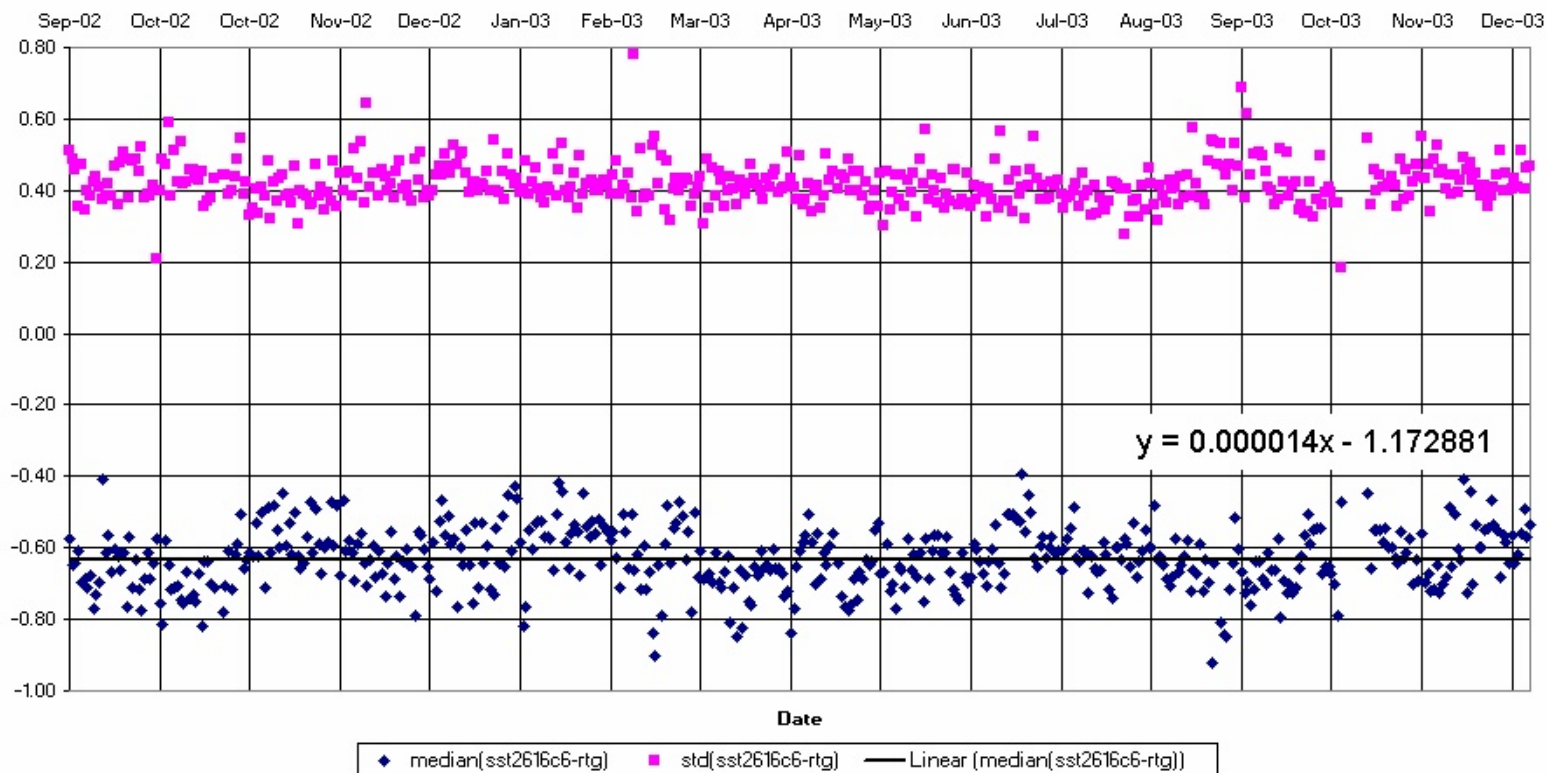


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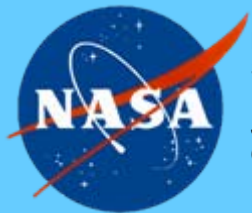
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Radiometric Stability of AIRS Channel 2616 cm^{-1}

Daily median and standard deviation of night (sst2616c6 - rtg.sst) for $|\text{lat}| < 40$ degree ocean viewd at $|\text{sza}| < 35$ degree. The median is - 0.64K, stable at the 5mK/year level



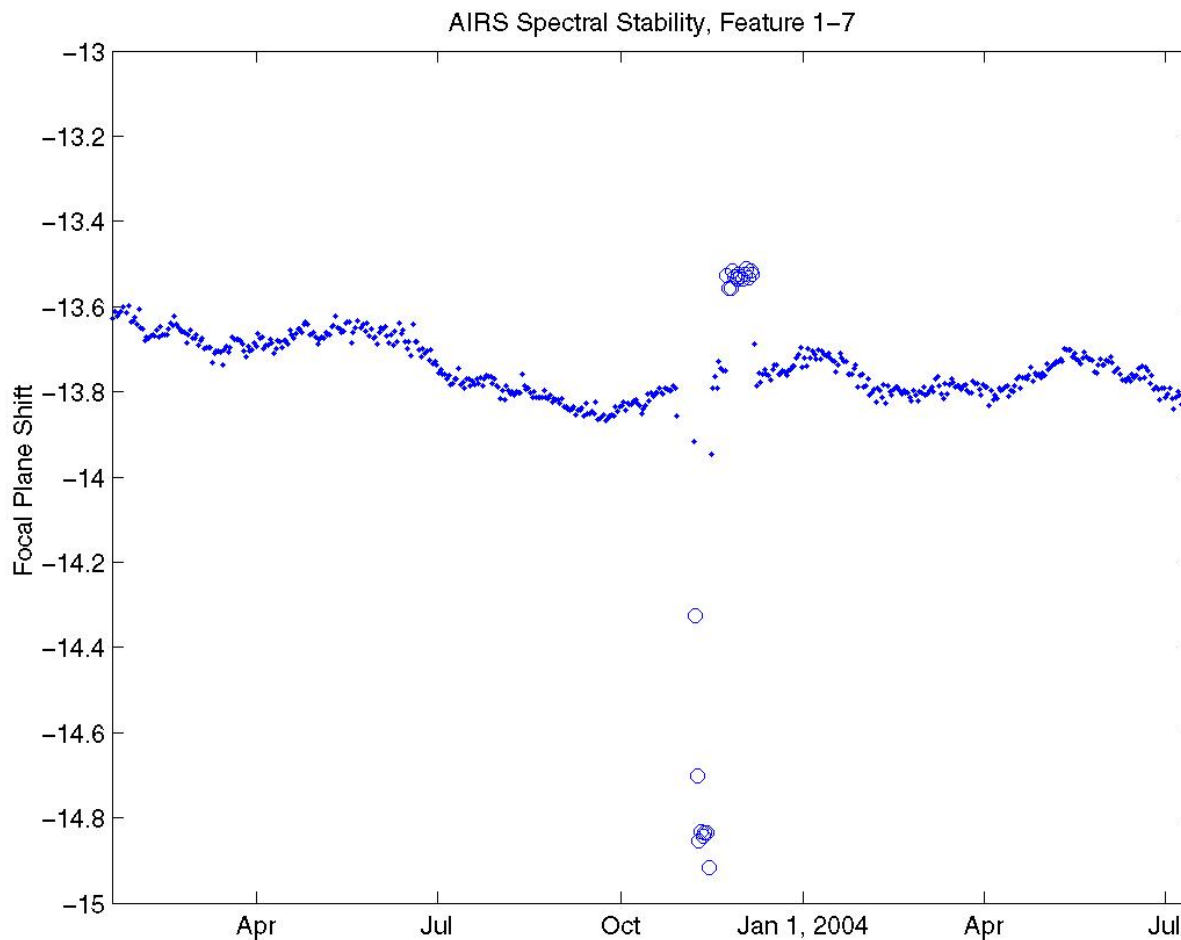
H.H. Aumann, JPL



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Spectral Stability of AIRS



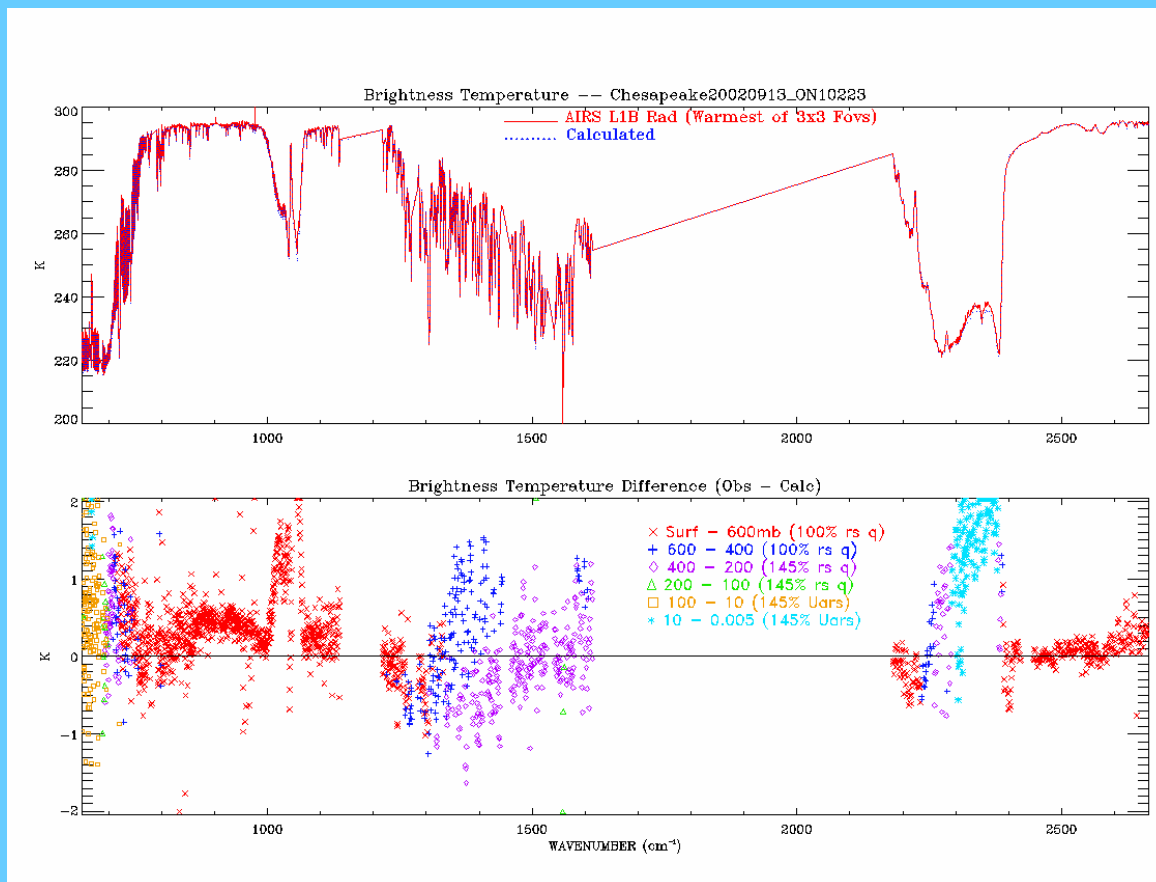


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Obs - Calc

- Clear ocean footprints
- Calculated from radiosonde observations
 - *climatology was used to extend data to TOA*
- Window regions are better than 0.5K



Luke Chen, Barney Farmer, Eric Fetzer (JPL)



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Standard Product Activation / Validation Timeline

| | Version | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 |
|------------------------|---------------------------|-------------------------|----------|----------|----------|----------|
| | Activation Date | 9/15/03 | 10/15/04 | 10/15/05 | 10/15/06 | 10/15/07 |
| Radiance Products (L1) | | Ocean | Land | Polar | Global | Global |
| | AIRS Radiance | Prov | Val2 | Val3 | Va4 | |
| | VIS/NIR Radiance | Prov | Val2 | Val3 | Val4 | |
| | AMSU Radiance | Beta | Prov | Val2 | Va3 | Val4 |
| | HSB Radiance | Beta | N/A | N/A | N/A | N/A |
| Standard Products(L2) | | | | | | |
| | Cloud-Cleared IR Radiance | Beta | Val2 | Val3 | Val4 | |
| | Surface Temperature | Beta | Val1 | Val2 | Val4 | |
| | Temperature Profile | Beta Prov | Val2 | Val3 | Va4 | |
| | Humidity Products | Beta | Val1 | Val 2 | Val3 | Val4 |
| | Cloud Cover Products | N | Val1 | Val2 | Val3 | Val4 |

Beta = Not suitable for
scientific investigations.
Consult with AIRS Project
on regional status.

Prov = Provisionally
validated. Useable for
scientific investigations with
caution. Validated for non-
polar, night, ocean only.

Val1 = non-polar, day/night, ocean.
Val2 = Val1 + land.
Val3 = Val2 + polar
Val 4 = Global All Cases



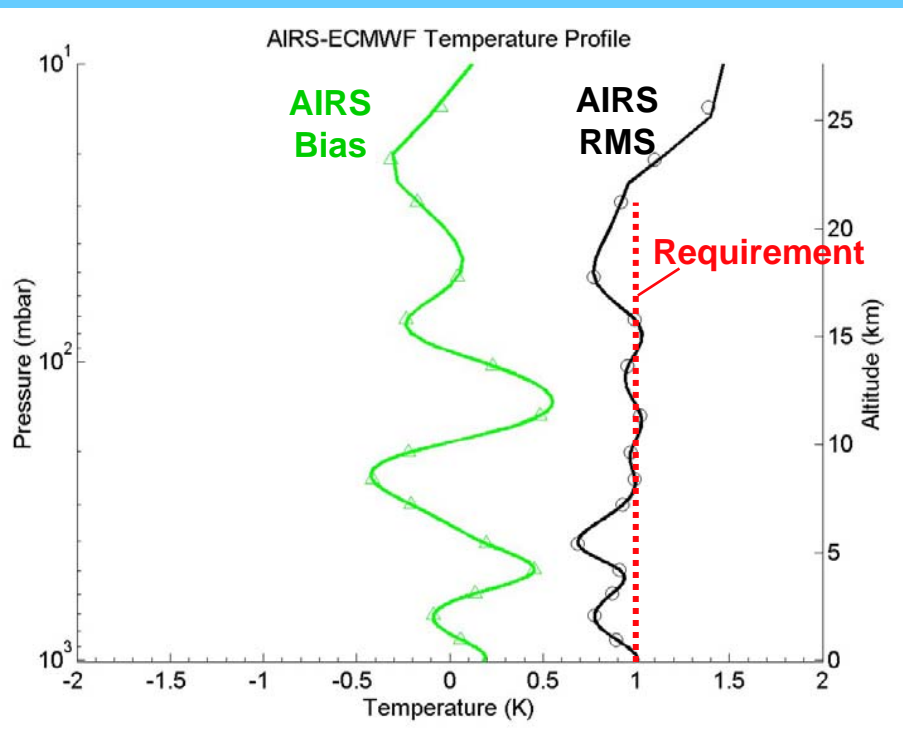
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Temperature and Water Vapor Accuracies

Temperature Profiles Accurate to 1K/km to 30 mb

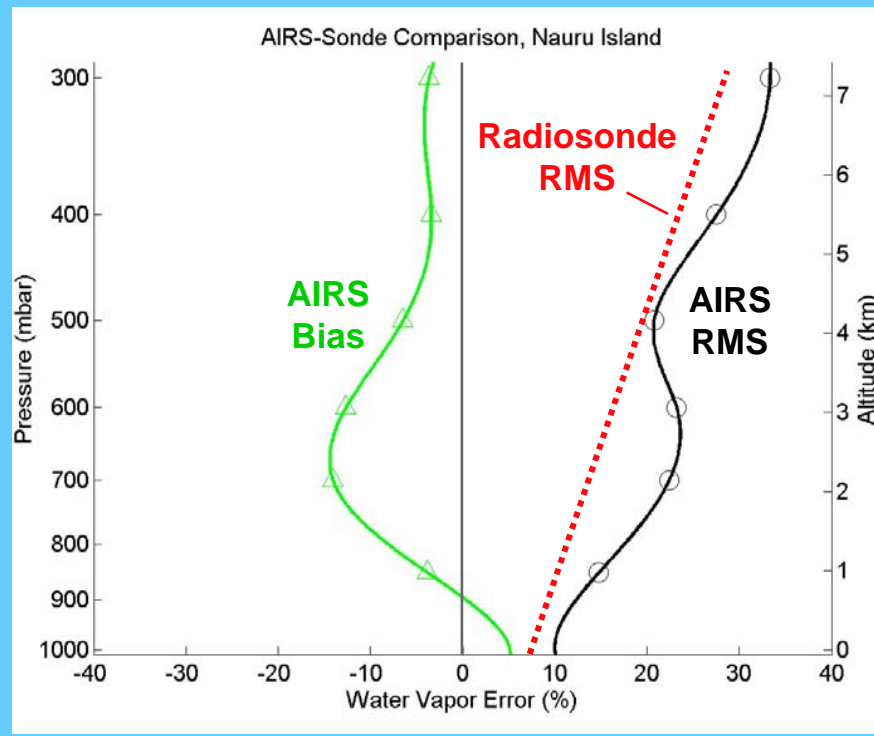
Ocean, Mid Latitude vs ECMWF



(T. Hearty/JPL)

Water Vapor Profiles Match Observations

Nauru Island Radiosondes

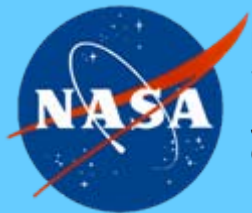


(E. Fetzer/JPL)



Cloud Clearing vs Hole Hunting

- **Hole hunting retrieval works less than 10% of all AMSU observations**
 - *Less than 10 % of all AMSU observations over ocean have at least one clear AIRS footprint (H H Aumann)*
 - *Clear footprint means the effect of cloud on AIRS radiances is less than 1K.*
- **With cloud clearing, we can raise the retrieval yield to 40 ~ 60%**
 - *Cloud clearing works on non-uniform cloud cover with cloud fraction < 80%*
 - *Cloud clearing method tends to produce SST outliers*
 - *Cloud clearing assumption fails often even over ocean*
 - *SST outlier is defined to be $\text{abs}(\text{SST-Forecast}) > 3K$*
- **Numerical Weather Prediction applications require outlier rate of less than 1%**
 - *AIRS developed QC methods to reduce SST outlier rate to less than 1% without using forecast SST. The yield rate was about 30% over water.*
- **Climate applications require unbiased sampling**
 - *Cloud clearing implies retrieving around clouds, not through clouds*
 - *Cloud clearing works better with less cloud, and hence tends to be drier*



New Quality Control for Version 4.0

- **Old version (v3.5) outputs combined MW/IR products 40% of all retrievals**
 - Otherwise outputs retrievals based on MW channels and stratospheric IR channels.
 - Includes retrievals with cloud fraction < 80%
 - RetQAFlag was used to remove SST outliers
- **New version outputs combined MW/IR products when cloud fraction < 90% (84% of all cases) with quality flags indicating the validity of:**
 1. Cloud parameters, OLR, water vapor, ozone, T(p) above certain height (currently 200 mb) (84%)
 2. T(p) above certain height (currently 3km above surface) and land surface(54%)
 3. T(p) for the lowest 3 km (28%)
 4. Surface skin temperature over ocean (12% of ocean cases)



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AIRS Level 3 Products

- **Gridded data products at 1 degree by 1 degree resolution**
 - *Separate Ascending/Descending global grids*
 - *MW only products as well as combined MW/IR products*
 - *8 day and monthly as well as daily*
 - *Will be released to public in version 4.0, Winter 2004*
 - *Mean, count, and standard deviation*
 - *Plan to add quantization products*
 - Statistical distribution of data points within a bin
- **Level 3 parameters**
 - *Temperature and water vapor profiles*
 - *Surface parameters (skin temp, spectral emissivity)*
 - *Cloud parameters (cloud fraction, cloud top pressure)*
 - *Outgoing Longwave Radiation (cloudy and clear)*
 - *Total column of water vapor, ozone, cloud liquid water*

S Granger

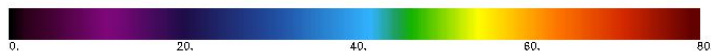
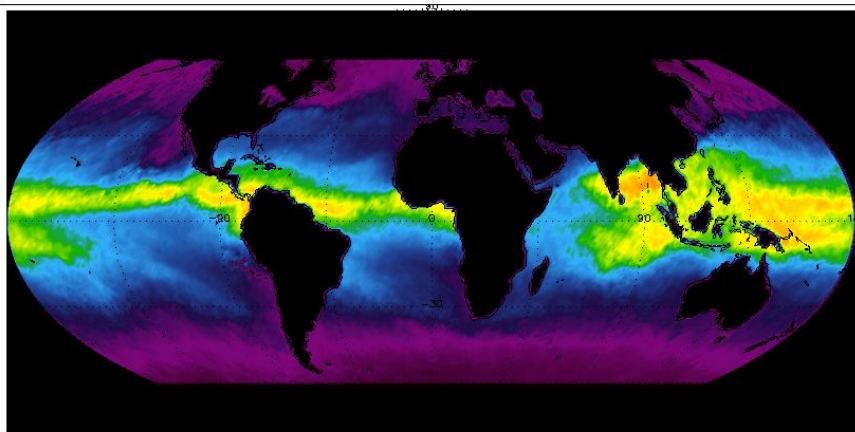


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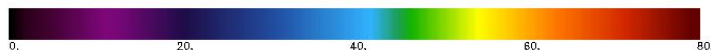
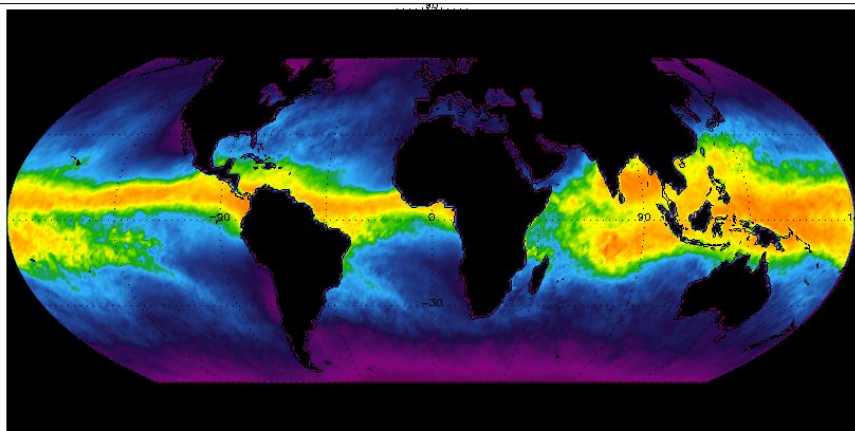
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Level 3 Sampling Issue

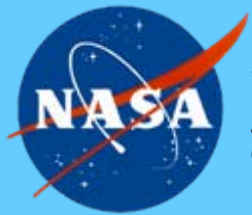
Monthly Mean Total Precipitable Water Vapor (Descending, Accepted Cases, MW/IR)



Monthly Mean Total Precipitable Water Vapor (Descending, RTtype < 100, MW Only)



- **Top: Total Precipitable Water Vapor for all accepted cases**
 - *Combined MW/IR retrievals*
 - *Global (ocean grid points between 50N and 50S) mean of 28.92 mm*
- **Bottom: MW Only Total Precipitable Water Vapor**
 - *Global mean of 34.32 mm*
- **The difference is due to MW only algorithm bias (~3 mm) and to sampling difference**
 - *Cloud Clearing works better when less cloudy, hence drier*
- **Even the lower figure is expected to have dry bias**
 - *MW only retrieval fails when precipitating*

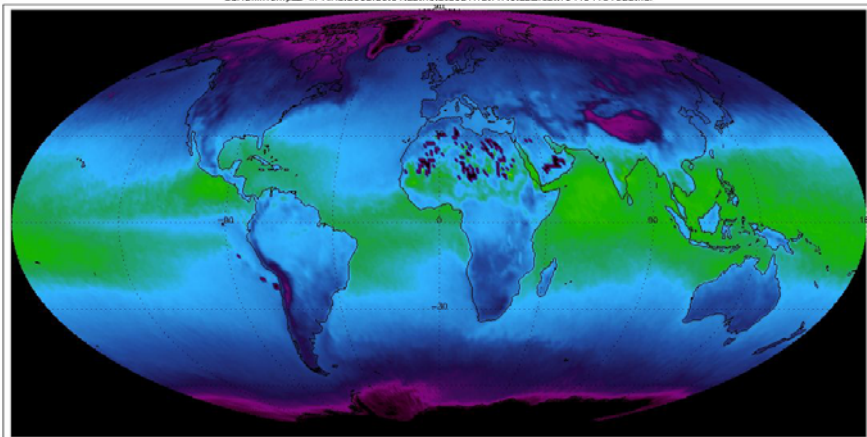


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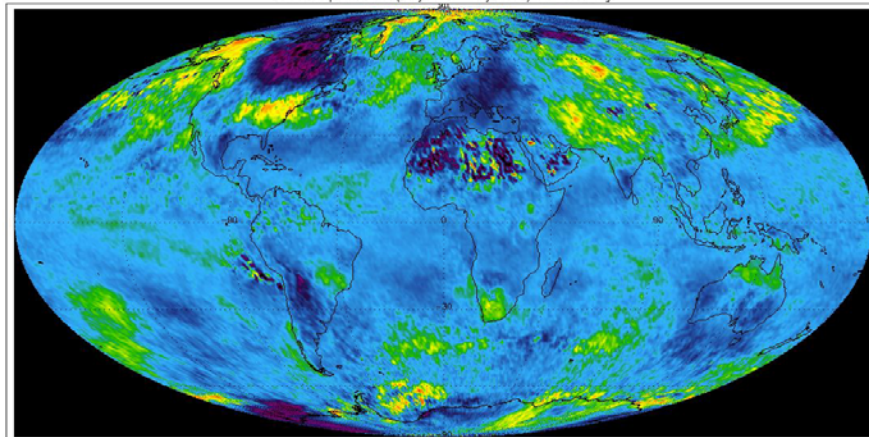
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Monthly Mean Surface Skin Temperature

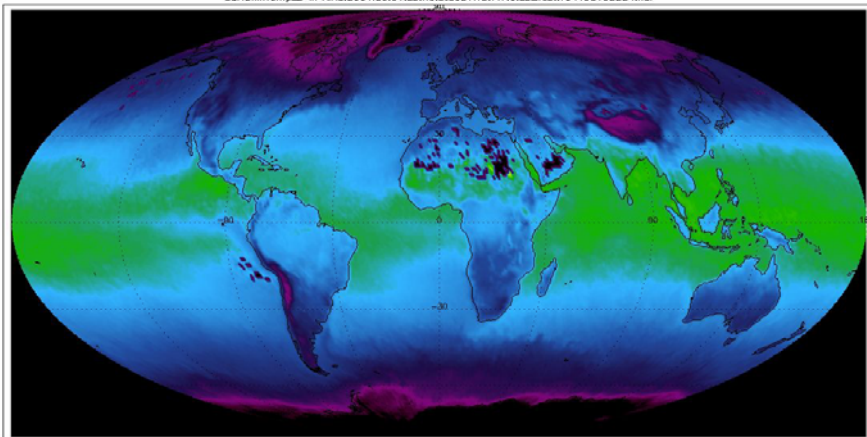
SurfSkinTemp_D In AIRS.2003.05.01.L3.RetStd031.v3.7.7.0.L3_Test.T04194131623.hdf



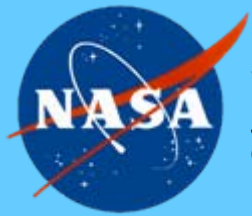
SurfAirTemp Difference (May 2004 - May 2003) for descending



SurfSkinTemp_D In AIRS.2004.05.01.L3.RetStd031.v3.7.7.0.L3_Test.T04190102224.hdf



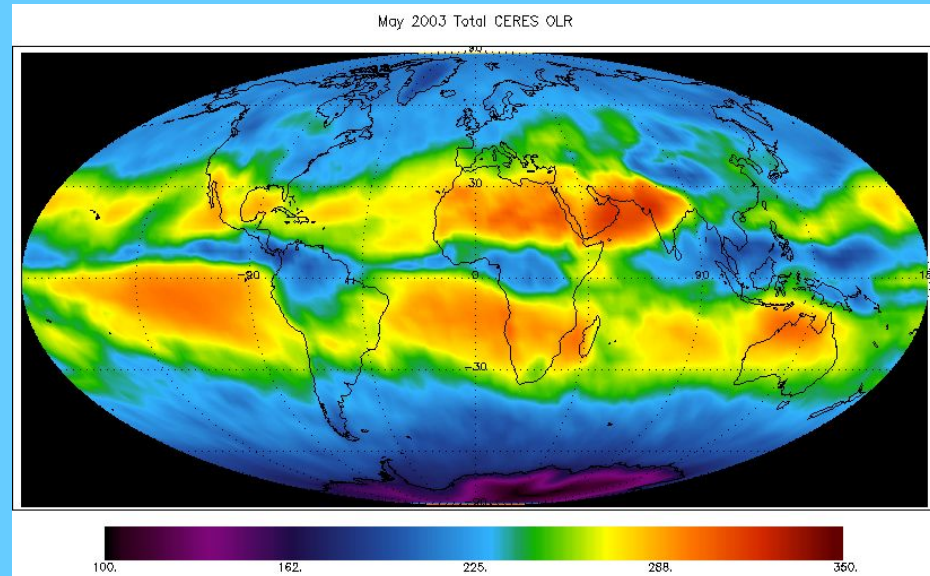
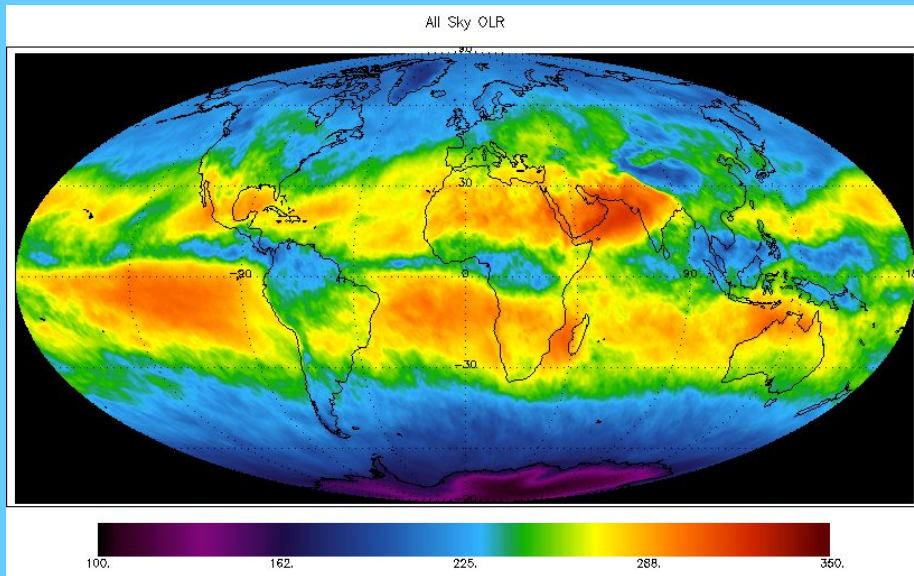
- Monthly mean SST for 2003(top left), 2004(bottom left) and the difference (above) for descending orbits
- Were Canada and Europe colder in 2004 than in 2003?



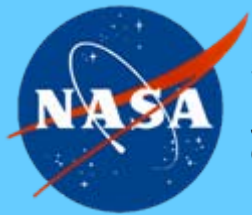
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Outgoing Longwave Radiation from AIRS



- Monthly means from AIRS (lef) vs CERES (right) for May 2003
- Both are gridded at 2.5 degree resolution.

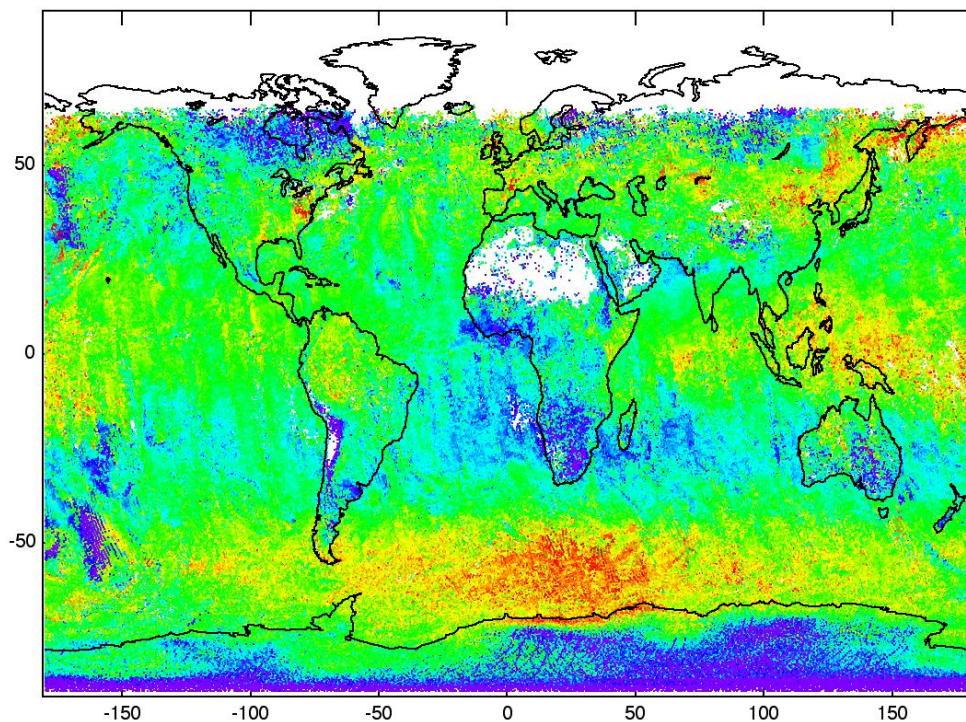


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Ozone Validation

(AIRS - TOMS) / AIRS column ozone difference
January 2003 daytime, v3.6.0 processing



$\frac{\text{AIRS} - \text{TOMS}}{\text{AIRS}}$ (%)



-10 -5 0 5 10 15
Color scale limited to $\pm 3\sigma$ of mean

Average Differences

50°S - 50°N

all: 3.1 ± 5.4 %
>99% ocean: 3.0 ± 4.8 %
>99% land: 3.7 ± 7.1 %

FWI - 5/20/04

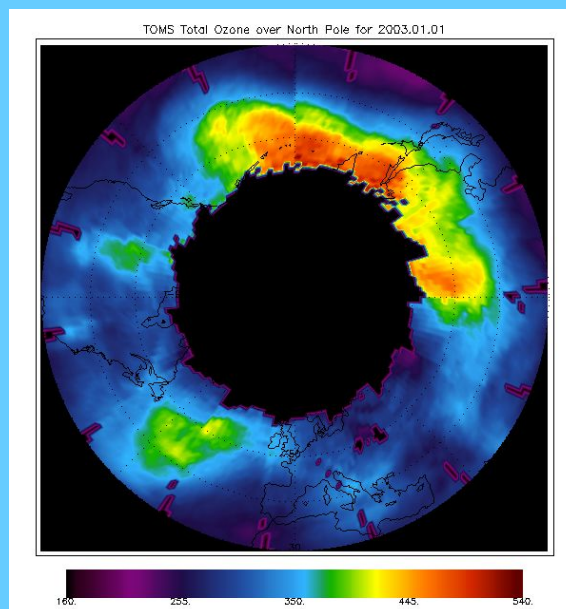
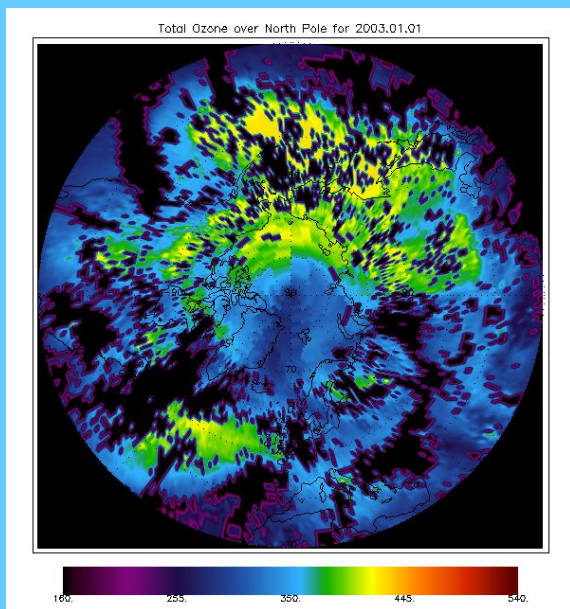
F W (Bill) Irion



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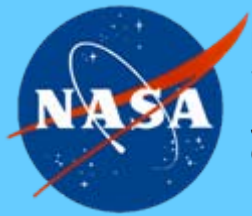
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Ozone map over polar night



QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

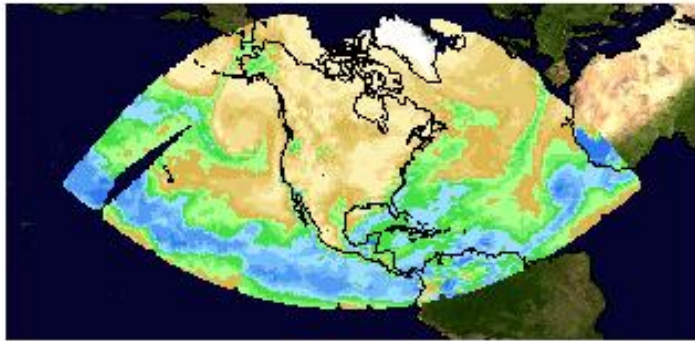
- AIRS (left) vs TOMS (center) Total Ozone Column Amount for January 1st, 2003
- Movie (right) of daily maps of total ozone clearly show circulation around the night pole in January 2003



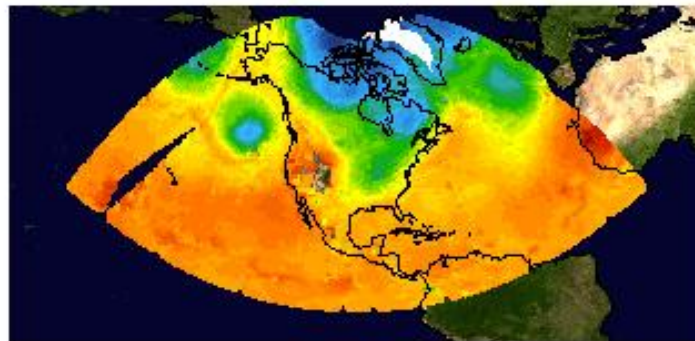
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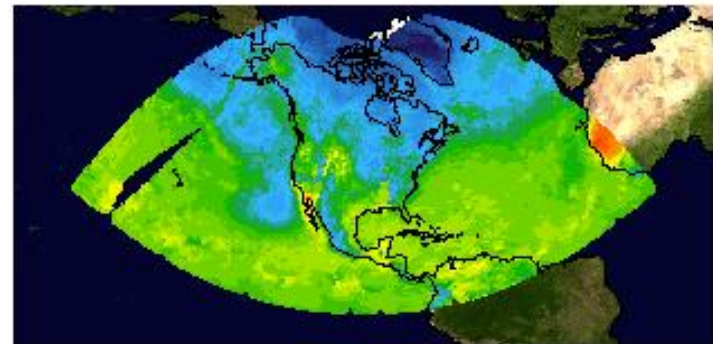
Near Realtime Weather Products over N America



Total Precipitable Water Vapor



700 mb Temperature



Surface Skin Temperature

- Click on daily weather maps in AIRS home page
<http://airs.jpl.nasa.gov/>
- This has near real time weather products over North America
- These are sample maps for August 15, 2008
(Available on Aug 16)
- We also track many hurricanes



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Sounder Development at JPL

- **T Pagano is involved with Ball Aerospace's development of Spaceborne InfraRed Atmospheric Sounder (SIRAS) on GEO/MEO**
 - *Grating Spectrometer*
 - *AIRS follow-on*
 - *Selected by NASA Instrument Incubator Program in January 2003*
- **B Lambrigtsen is working on Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR)**
 - *Also have applications on MEO*
 - *Channels similar to AMSU channels*
 - *Also sponsored by NASA IIP*